Uninterruptible Power Supplies: A Data Center Efficiency Opportunity

The Problem

Data centers depend on uninterruptible power supplies (UPSs) for continuity of service in the event of a power outage. These systems were believed to consume a large amount of energy in both standby and active modes, yet until now that energy use has not been accurately characterized. Also, UPSs vary widely in efficiency but data on efficiencies of existing products have not been compiled and there has been no uniform labeling requirement to encourage the use of more efficient UPSs.

The Solution

A detailed study characterized the efficiencies of various types of UPSs under a variety of operating conditions, proposed an efficiency label for UPSs, and estimated the current energy use of the existing stock of UPSs and the potential savings if efficiency standards were in place.

Features and Benefits

By characterizing current UPS efficiencies and estimating their savings potential, the study provides results that could help to develop a market for more energy-efficient UPSs.

Current efficiencies. Measurements of efficiency were taken under controlled factory conditions and in the field for a number of different types of UPS. Efficiencies varied widely, even among units of the same type (**Table 1**). All types tend to be more efficient at full load than at part load—an important observation because UPSs in a data center environment typically operate at or below 50 percent of their rated active power output. This is primarily because they are often part of a redundant system in which they share the load with another UPS but must be sized to carry the full load. The measured efficiency of a given UPS also decreases by 1 to 2 percent when meeting nonlinear loads such as the switch mode power supplies used in low-end servers. The most efficient configurations were flywheel and delta-conversion designs.

The UPS types found to be most relevant for data centers include:

- Delta conversion, which is a proprietary topology that uses a special transformer configuration to interface between the load and utility power, with a "delta" inverter in the transformer secondary to regulate input current and power.
- Double conversion, also called "online," is the most common configuration because it is capable of completely isolating sensitive IT loads from unconditioned utility power.
- Line-interactive, which allows the load to be powered from the line until a disturbance is detected, at which time the load is disconnected from the line and fed from an energy storage device—batteries, capacitors, or flywheels. This approach can be quite efficient because under normal conditions, the load is directly connected to the source.

Proposed efficiency labels. The wide range in UPS efficiency suggests an opportunity to encourage higher-efficiency designs through product labeling and standards. To promote UPS energy efficiency, the researchers designed a product label that lists efficiency in different modes of operation, estimates the annual energy consumption, and shows where a product falls in relation to the highest available efficiencies (**Figure 1**). The label design is based on a proposed European label, which should help to harmonize international efforts to promote UPS efficiency.

Energy use and savings potential. Researchers estimate that the data center/IT sector uses roughly 7.1 billion kilowatt-hours (kWh) of electricity per year. In California, home to about 15 percent of the nation's data center floor space, data center UPSs consume about 1 billion kWh of electricity—about 0.41 percent of the state's electricity use.

The introduction of efficiency standards would result in considerable savings—nationwide, about 2.8 terawatt-hours (TWh) per

Table 1: UPS efficiency varies with type and load

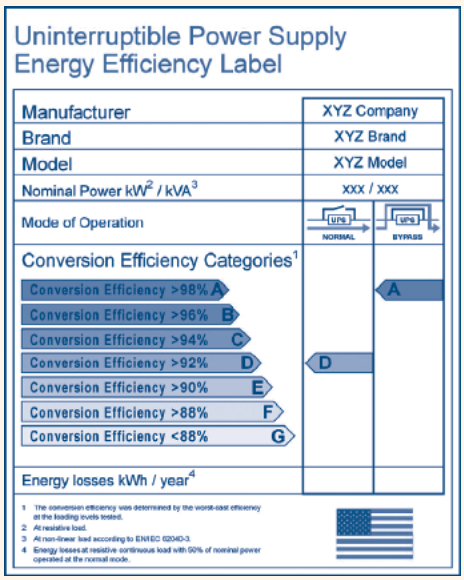
The efficiency of UPSs varies widely even for units of the same type. Full-load efficiencies are higher than part-load efficiencies.

	Efficiency			
UPS type	at 25% load	at 50% load	at 75% load	at 100% load
Delta conversion	93–94	96–97	97	97
Double conversion	81–93	85–94	86–95	86–96
Line interactive	NA	97–98	98	98
Standby	NA	NA	NA	NA
Average of all units	**86**	**89**	**90**	**90**

Notes: NA = not available; UPS = uninterruptible power supply.
A straight average was used in the table.

Figure 1: Proposed UPS efficiency label

An energy-efficiency label such as the one shown here would enable buyers to consider energy efficiency as one of their criteria for buying an uninterruptible power supply (UPS) system. The label is designed to be similar to one proposed by the Swiss Federal Office of Energy.



year with a mandatory program and 0.71 TWh/year with 25 percent compliance in a voluntary program. In California, corresponding savings would be 0.42 TWh/year and 0.11 TWh/year. Even more savings would result if UPSs installed in small offices, industrial facilities, hospitals, and units smaller than 5 kilovolt-amps (kVA) were included in the analysis.

Accounting for reduced facility cooling needs would almost double the savings potential. Less cooling would be required because less waste heat is generated from the conversion and storage equipment. Up-front savings are also possible from reduced capital investment in equipment and reduced real-estate investment from smaller equipment footprints.

Applications

The data and analysis apply to the data center/IT market, which accounts for about two-thirds of installed UPS units in the U.S. The analysis also excludes units smaller than 5 kVA.

California Codes and Standards

Currently, there are no standards for UPS in California. However, this research may be used to guide future standard-setting efforts or the adoption of a voluntary label approach.

What's Next

This work inspired a demonstration of the benefits of eliminating some of the typical data center power-conversion steps. The demonstration showed how direct current (DC) power could be effectively used in data centers. Both this UPS study and the DC power demonstration have raised awareness of the opportunity to improve power distribution efficiency. Organizations such as Green Grid, an association of IT professionals seeking to raise the energy efficiency of data centers (www.thegreengrid.org), are examining the possibilities for putting these measures into practice.

Collaborators

The organizations involved in this project include Lawrence Berkeley National Laboratory and its subcontractors, EPRI Solutions, and Ecos Consulting.

For More Information

For more information, please contact the California Energy Commission researcher listed below. A Microsoft Excel calculator for estimating savings from more efficient UPSs and other measures is available at http://hightech.lbl.gov/server-ps-tool.html.

More PIER Technical Briefs can be found at www.energy.ca.gov/research/techbriefs.html.

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About PIER

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